

**STATEMENT OF WORK
For
SPACE TECHNOLOGY RESEARCH AND DEVELOPMENT**

1.0 INTRODUCTION

The principal purpose of this contract is to provide support to the Space Technology Division at NASA Ames Research Center to carry out their varied research programs. This document describes the current and anticipated research programs of the Division. The major objective is the development of technologies for use in the design and fabrication of prototype vehicles that travel at hypervelocities in the atmosphere of Earth and other bodies in the solar system. Other projects include NASA missions in nanotechnology, advanced materials, sensors and devices.

2.0 SCOPE OF WORK

2.1 GENERAL SCOPE

The scope of the effort to be performed within the Space Technology Division is described in this section.

The Contractor shall provide multidisciplinary engineering research and development, pursuant to task assignments issued by the Contracting Officer. These services shall include the personnel, facilities, equipment and materials (unless otherwise provided by the Government) to accomplish the tasks.

Task assignments will be issued to perform services in the following areas: project management, systems engineering, research and analysis, design and development, testing, computer modeling, technical writing,, support for third party Quality System, administrative support, computer system administration, organizing and facilitating technical and working meetings and invitational travel for outside researchers, and other functions, which may include fabrication and fabrication support, necessary to complete projects. The Contractor shall provide management and administrative functions necessary to effectively and efficiently manage the work performed under this contract.

The Contractor shall perform services required by task order in the following technical areas:

- a) chemistry and physics of hypersonic, chemically reacting, and radiating flows
- b) aerothermodynamic analysis of entry systems
- c) development, modification, and application of computational fluid dynamics tools
- d) aeronautics and space vehicle trajectory analysis
- e) materials science and engineering of ablative, reusable and multi-functional thermal protection materials
- f) experiment planning, execution, and analysis for high-enthalpy testing of materials and real-gas phenomena
- g) quantum computing and pre-biotic geochemistry mechanisms
- h) educational outreach
- i) internship employment opportunities to support STRAD requirements for NASA programs and to provide students with exposure to public service, enhancement of their educational experience, and financial support to encourage their educational goals

Facilities and labs which may be used during performance of this contract include, but are not limited to:

- a) Electric Arc-driven Shock Tube (EAST)
- b) ballistic range complex
- c) arc jet complex
- d) ceramics lab
- e) materials development lab
- f) materials characterization lab
- g) ultra high temperature ceramics lab

Specific requirements will be defined for each task order according to the current and future needs of programs and projects involving the Space Technology Division. The Contractor may be tasked to accomplish either an entire project from conception to operation, or a specific part of a project such as design or testing.

2.2 CONTRACTOR RESPONSIBILITIES

The Contractor's responsibilities shall include the management of contractor and subcontractor personnel, timely and effective implementation of task assignments, contract and monitoring of contract and subcontract performance, management of scheduled deliveries, and timely and effective reporting to the Government. These responsibilities shall also include efficient cost management methods as well as procedures to ensure that the Government is aware of task assignment status and progress achieved. Management includes managing financial, contractor and subcontractor personnel, and facility resources as well as conforming to established NASA policies and to budgetary guidelines. Most of the work will be performed on-site at Ames Research Center, Moffett Field, California.

The Contractor shall participate with the Government to upgrade and maintain required plans, procedures, and work instructions in order to maintain the organization's compliance with any third-party quality system and shall participate in any audits to maintain the quality system certification. Where the Contractor has primary responsibility for a functional or business area, the Contractor shall have primary responsibility for maintaining compliant documentation associated with that area.

The Contractor shall provide qualified management personnel, organizational structure, procedures and administration support functions to effectively and efficiently manage the work performed under this contract. The management and administrative structure shall provide a single point of contact for interface to the Contracting Officer's Technical Representative (COTR) and shall provide procedures and management supervision to ensure compliance with applicable government regulations for accomplishing this contract.

The Contractor shall be responsible for ensuring that all contractor and subcontractor personnel engaged in performance of this Statement of Work have appropriate qualifications, knowledge, and certification to perform work in accordance with the task assignments. The Contractor must have the flexibility to hire personnel at all appropriate levels of skills and experience, including, but not limited to, university students, post-docs, technicians, junior and senior research scientists and engineers. The Contractor

will support the Space Technology Division's goals to acquire a highly skilled workforce that is aligned with NASA missions and continues to value intellectual advantage and synergy that is made possible by a diverse workforce. The Contractor will ensure that all foreign national visitors and all employees have completed the required background checks, approvals and clearance requirements for access to the NASA Ames Research property.

The Contractor shall provide computer system administration support necessary for the fulfillment of the work of this contract, when tasked by the Government. This work shall include on-site IT support services and trouble calls of desktop, laptop, workstation and server computers and associated peripheral equipment and office equipment, such as fax machine and color printers for the Space Technology Division.

Research office and laboratory space, computer hardware, and software, deemed necessary for the direct fulfillment of the task orders will be provided by the Government. The Contractor may purchase, with COTR approval, and in accordance with the Subcontracts clause at FAR 52.244-2, any materials (consumables and non-consumables) necessary for the fulfillment of their task requirements.

The Contractor shall comply with the health and safety requirements contained in APG 1700-1 and the system safety and mission assurance requirements in NPG 7120.5, NASA Program and Project Management Processes and Requirements, and Space Technology Division processes and procedures.

The contractor shall also support educational outreach and internship employment opportunities to augment NASA programs. NASA Ames supports various student employment programs, from high school to postdoctoral levels, which provide students with exposure to public service, enhancement of their educational experience, and financial support to encourage their educational goals.

3.0 REQUIREMENTS

3.1 GENERAL

3.1.1 Technologies

The Space Technology Division develops technologies for use in the design and fabrication of vehicles that travel at hypervelocities in the atmospheres of the Earth and other bodies in the solar system. Flight envelopes include access to orbit and reentry, planetary entry, and high altitude aerobraking. Relevant flow physics are studied using both theoretical and experimental means. Thermal protection materials and systems are developed which can withstand these environments. High enthalpy facilities are operated and developed in support of the experimental work, and research into innovative facilities for the future is carried out as well. Multidisciplinary research is conducted across branch lines.

3.1.2 Customer Focus

The Division maintains a customer focus and is committed to ensuring the transfer and use of its technologies by the commercial aerospace industry, the rest of NASA, other government laboratories and academia. The Division develops and applies technology

in support of numerous projects for a variety of customers including industry, DOD, and other NASA centers. Near term projects include Crew Exploration Vehicle (Orion), Mars Science Laboratory (MSL), Hypersonics, and projects related to the In-Space Propulsion, New Frontiers, Shuttle Return-to-Fight Programs, and others. Longer-term missions, requiring a wider range of advanced technologies, include aerobraking space exploration missions, and other highly reusable launch and entry vehicles. A project office is located at the division level to provide project management and coordination across the branches. In addition, the division maintains a basic research program that addresses advancements in the underlying technologies that are fundamental to all of these missions.

3.2 SPECIFIC REQUIREMENTS

3.2.1 Administrative Support

The Division requires technical information management support for both project-related tasks and general support tasks. Administrative support is required to ensure that technical publications receive the necessary approvals and reviews, and that the Division web sites conform to NASA requirements for information release and ease of access.

3.2.1.1 Contractor Responsibilities

The Contractor may be required, by task order, to provide the following support:

- a) Technical assistance for web development, preparation of displays, posters, brochures, manuals, publications, presentations, and travel orders.
- b) Preparation of graphics and presentation materials
- c) Management of archival records and documents
- d) Assistance in financial and administrative support, including but not limited to purchase and service requests, and bankcards.
- e) Provide administrative support in the development of non-technical publications, such as marketing plans, strategic plans, and reports; control and preparation of forms and documentation; and management of laboratory and office supplies.

3.2.2 Reacting Flow Environments

3.2.2.1 General

This area includes:

- Applied aerothermodynamic analysis of current and future NASA launch vehicles, crewed spacecraft, and unmanned planetary probes and Earth entry vehicles using in-house Computational Fluid Dynamics (CFD) and shock layer radiation codes
- Studies of real gas physics in hypersonic, reacting gas flows and development/implementation of new physical models into modern CFD and shock layer radiation codes
- Participation in design activities in support of vehicle and mission studies that rely on aerothermal environment modeling in conjunction with Thermal Protection

System (TPS) sizing and selection, trajectory trades, and overall vehicle performance/feasibility trades

- Experimental efforts that are complemented by a theoretical/computational program. Numerical algorithm enhancements and modifications to existing in-house reacting flow solvers are assessed and implemented as appropriate based on the ongoing research/project requirements. Emphasis is placed on code validation by laboratory experiment and available flight data
- Planning and implementation of flight experiments for aerothermodynamic research
- Supporting integrated design system efforts as needed to improve the vehicle/mission design process by injecting higher fidelity modeling earlier in the design process

3.2.2.2 Contractor Responsibilities

The Contractor shall be responsible for conducting research and performing applied analysis in the areas described above. Example specific problem areas are given as follows:

- a) Validate, optimize, and apply new Computational Fluid Dynamics (CFD) algorithms in support of thermochemical model development that will allow the design and development of advanced Earth-to-orbit and planetary entry vehicles
- b) Support aerothermal environment prediction and TPS sizing analysis and design for hypersonic vehicle development projects, such as the Orion command module, including the application of CFD methods and other modeling capabilities
- c) Develop, validate and apply radiation heat transfer calculation methods for the simulation of shock layer and wake radiation for blunt body hypersonic flows
- d) Develop and apply gas-phase kinetics, thermal nonequilibrium, transport, and surface chemistry models for use in simulation of hypersonic blunt body flows
- e) Develop and apply models for the simulation of the flow in high enthalpy facilities for the characterization of facility capabilities and traceability of test conditions to flight
- f) Perform systems analysis on vehicle systems to help guide investment of efforts in the Space Technology Division, including support of design activities in the Center
- g) Perform systems analysis for entry and descent phases of planetary entry vehicles
- h) Perform calibration/validation experiments in concert with theoretical aerothermodynamics for the validation of thermochemical modeling efforts
- i) Develop and apply advanced, state-of-the-art, diagnostics for real-gas testing and data acquisition in shock tubes, ballistic ranges, and arc jets
- j) Design and conduct experiments and models for ballistic range testing

3.2.3 Nanotechnology

3.2.3.1 General

The Ames Center for Nanotechnology (ACNT) performs fundamental research in nanoscience and nanotechnology and design and development of nanoscale sensors, electronic devices and materials.

3.2.3.2 Contractor Responsibilities

The Contractor may be required, by task order, to provide the following support:

- f) General administrative and Technical assistance including:
 - (1) Web development, preparation of displays, posters, brochures, manuals, publications, presentations, and travel orders. The web development includes maintaining the ACNT database.
 - (2) Management of ACNT archival records and documents
 - (3) Assistance in financial and administrative support including purchase and service requests. Develop and maintain spreadsheets for financial accounting and tracking of all ACNT expenses: contracts, purchase and service requests, job orders, and bankcards. Assist Space Technology Division financial managers in reconciliation of ACNT finances with NASA financial accounting system
 - (4) Sponsor seminar speakers and guests to support NACNT activities
 - (5) Sponsor student interns and faculty visits for education outreach. Sponsor up to 6 full time students

b) Pre-biotic Geochemistry Mechanisms

Computational study of redox chemical reactions on iron sulfide and iron pyrite mineral surfaces with the goal of testing key components of Wachtershauser's "iron-sulfur world" Hypothesis of prebiotic chemistry at hydrothermal vents on the ocean floor. The long-term goal is to study the coupling of the carbon dioxide reduction mechanism to form methane with the oxidative growth of iron-sulfur mineral surfaces.

c) Quantum Computing:

The purpose of this task is to develop a theoretical framework for the family of physics-based algorithms and architectures in support of the NASA and DoD tasks in the areas of revolutionary computing and quantum sensors. It is focused on the analysis of algorithm complexity and design of novel architectures that takes into account quantum effects in sensing and computation. The emphasis is in solution of hard combinatorial optimization problems.

3.2.4 Thermal Protection Materials and Systems

3.2.4.1 General

Activities include development, fabrication, testing (both ground and flight), and computer modeling and analysis of advanced Thermal Protection System (TPS) materials and assemblies for hypersonic vehicles and spacecraft. These efforts include multidisciplinary work on flowfield/surface interactions, TPS/structural interactions, and analysis and instrumentation for flight and ground materials characterization and aerothermal heating tests. Research and technology development is pursued in some base R&T areas as well as in support of specific programs such as reusable launch vehicles, crew exploration vehicles, planetary probes, fundamental aeronautics, and sample return missions. Certain continuing tasks also are required to support, maintain, and upgrade computational and experimental facilities, and software.

3.2.4.2 Contractor Responsibilities

Contractor personnel perform specific tasks to achieve milestones and meet delivery schedules for tasks in the following areas:

- a) Assure the correct operation and efficient use of local and networked computing systems used for research and project activities including UNIX and Linux workstations, and personal computers. Stay abreast of new hardware and software developments, and provide expert advice on the procurement of new hardware and software. Provide required backups, maintenance and problem solving to help assure reliable computer operations as required. Continue the development, enhancement and distribution of the TPSX material database
- b) Monitor schedules, operations and modifications of Branch analytical and materials characterization labs. The equipment involved includes a scanning electron microscope, IR spectrometer, X-Ray diffraction unit, energy dispersive X-Ray analyses unit, inductively coupled plasma spectrometer, laser particle size analyzer, TGA, and side-arm reactor. Investigate and suggest new equipment acquisitions and to maintain efficient and effective support of Branch activities
- c) Perform data acquisition and analysis in Branch analytical and materials characterization facilities as required in support of research and project activities
- d) For Branch Ceramic and TPS Development Laboratories, fabricate and modify TPS materials to prepare flight hardware and test articles. Also machine metals and ceramics, spray coatings, apply adhesives, and work with flexible insulation as needed. Travel may be required to install, repair, and inspect articles off site
- e) Provide test engineering for the Division's Arc Jet Complex. Activities include all aspects of testing such as evaluation of test feasibility, design of test models including instrumentation, and pre and post test analysis for various programs and research activities
- f) In Branch Laboratories, pursue development of advanced ceramic composites, ceramic/polymer composites, rigid and flexible ceramic TPS, insulations, and ceramic coatings. Models will be fabricated and tested to determine the optimum processing conditions for producing new lightweight ceramics, ablators, and other

hybrid materials and systems. Optimization will consider performance, fabrication safety, cost and other factors. Provide equipment training for new users

- g) Support projects as required by doing research and development, planning and scheduling, interacting with others in the Division, Center or at other NASA centers or industry. ,
- h) Apply computational tools for design, analysis and optimization of instrumentation, models, TPS and structural components and assemblies for ground and flight experiments and vehicles. This work utilizes in-house codes written primarily in FORTRAN and commercial software such as Pro/E and MSC.MARC. This work includes aerothermal performance analysis and sizing optimization of TPS components and assemblies. Finite element calculations using the MARC software will include thermal analysis as well as thermal and mechanical static and dynamic stress analysis of TPS, structural, and instrumentation components and assemblies
- i) Develop computational models and tools as required in support of projects and to achieve milestones. These efforts will focus on improved methods for non-CFD aerothermal heating estimation, coupling of aerothermal heating modules with material response solvers (one-dimensional and MARC), specialized software for analysis of laboratory and arc jet test results, and improved material response models for TPS materials
- j) Provide documentation support to maintain efficient organization of Branch, including travel, supplies, publication and paper documentation, editing, technical writing, and marketing,
- k) Support proposal development as required.

3.2.5 Travel

Contractor personnel may be required to travel for short periods of time to attend meetings, to participate in industry site visits, or to attend technical conferences. The Contractor will budget for these expenses as well as anticipated publication expenses in the submission of the response to a task order or modification to a task order.

3.2.6 CTO Accounting

Since tasks are internally funded by the ARC requesting organization, contractor expense accountability must be accomplished on a task basis.

3.3 PERFORMANCE MEASUREMENT

The Contractor shall adhere to the performance measurements detailed in each task order.

4.0 DELIVERABLES AND REPORTS

Contract deliverables and reports are identified and described in the Data Requirements List attachment to this contract. Task specific deliverables will be defined in each task.